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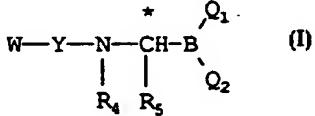
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(54) Title: PEPTIDE BORONIC ACID DERIVATIVES HAVING PROTEASE INHIBITING ACTIVITY

(57) Abstract

Peptidomimetics of formula (I), wherein W, Y, R₄, R₅, Q₁ and Q₂ are defined in claim 1 are potent thrombin inhibitors.



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PEPTIDE BORONIC ACID DERIVATIVES HAVING PROTEASE INHIBITING ACTIVITY

This invention relates to inhibitors of serine proteases involved in the blood coagulation process such as thrombin (factor IIa), factor Xa, factor VIIa, factor XIIa, kallikrein, plasmin, prolyl endopeptidase and Ig AI Protease.

5 Thrombin, the last enzyme in the coagulation system, cleaves soluble fibrinogen to fibrin, which is then crosslinked and forms an insoluble gel forming the matrix for a thrombus. When a vessel is damaged, the above process is necessary to stop bleeding. Under normal circumstances there is no measurable amount of thrombin present in plasma. Increase of the thrombin concentration can result in formation of clots, which can lead to
10 thromboembolic disease, one of the most common serious medical problems of our time.

Thrombin contributes to haemostatic control by means of several biological reactions. In addition to its primary function, the conversion of fibrinogen to fibrin, thrombin activates Factor XIII, which is responsible for the crosslinking of fibrin. Thrombin also acts by means of a positive feed back mechanism involving the activation of Factors V and VIII,
15 both of which are necessary for formation of thrombin from prothrombin. Thrombin has another essential role: its binding to platelets initiates platelet release and aggregation which is responsible for primary haemostasis.

The reactions of thrombin are further controlled by natural inhibitors in plasma. The
20 most important of these are antithrombin III and heparin. These two compounds have been isolated and are used therapeutically and prophylactically in conditions where there is an imbalance in the haemostatic mechanism with risk of prothrombin activation.

Orally active synthetic thrombin inhibitors would be useful as alternatives to the parenteral administration of these natural inhibitors. Much research in this area has resulted
25 in the synthesis of good inhibitors of thrombin in vitro, but as yet there is no really good candidate for oral therapeutic use. By imitating amino acid sequences of fibrinogen, the important natural substrate of thrombin, several good short peptide substrates for thrombin have been produced. These peptide substrates have also been derivatised to provide

inhibitors of the enzyme. Thus, the chromogenic substrates D-Phe-Pro-Arg-pNA and D-Phe-Pip-Arg-PNA mimic the sequence preceding the thrombin cleavage site. The corresponding reversible and irreversible inhibitors, D-Phe-Pro-Arginal and D-Phe-Pro-Arg-CH₂Cl show inhibition *in vitro* in the 10⁻⁸ M range. Chloromethylketones 5 are generally insufficiently specific to be ideal for therapeutic use, and the peptide aldehyde exemplified above has quite a low LD₅₀ value.

Factor Xa is the coagulation enzyme responsible for the generation of thrombin by limited proteolysis of its zymogen, prothrombin. On a weight for weight basis factor Xa is at least 10 times more thrombogenic *in vivo* than thrombin. This arises from the fact that 10 factor Xa is one step above thrombin in the amplifying cascade system, so that one molecule of factor Xa can generate many molecules of thrombin from its precursor. Its potency may also arise from the relatively slow removal of factor Xa by the body. Thrombin, unlike factor Xa, is rapidly cleared from circulating blood onto high affinity sites on the vessel wall.

15 The binding of tissue factor to factor VII represents a key event in initiation of blood coagulation after tissue injury. First it catalyses the activation of factor IX and factor X and secondly, trace concentrations of factor Xa and factor IXa (and conceivably other enzymes released from cells after tissue injury) convert zymogen factor VII/tissue factor complexes into highly active factor VIIa/tissue factor complexes.

20 The central position of factor Xa at the junction of the intrinsic and the extrinsic pathways as well as the crucial role of factor VIIa in initiating both the intrinsic and extrinsic coagulation pathways make factors Xa and VIIa suitable targets for modulating the haemostatic process.

Kallikrein is formed from prekallikrein by the action of factor XII, in the presence 25 of a negatively charged surface. Kallikrein in turn can cleave factor XII to factor XIIa, thereby forming a reciprocal activation system. Factor XIIa is the first enzyme of the intrinsic part of the coagulation system. The significance of the contact system is probably as a surface mediated defence mechanism, and a large scale activation of the system is normally seen during shock or disseminated intravascular coagulation (DIC). The role of 30 kallikrein at this stage is to cleave high molecular weight kininogen with the release of the

vasodilator, bradykinin. Bradykinin also causes increased vascular permeability, pain and migration of the neutrophil leucocytes. Inhibitors of kinin formation have been shown to be beneficial in certain types of inflammation, including arthritis and pancreatitis, and may be useful also in the treatment of asthma. The only substance that has attained clinical 5 significance as a kallikrein inhibitor, is aprotinin (Trasylol). Aprotinin is a polypeptide of molecular weight 6,500, and forms a stable complex with proteases, having a binding constant of 10^{-10} - 10^{-13} M.

Fibrinolysis is the process of enzymatic dissolution of fibrinogen and fibrin clots. Plasma contains a protein, plasminogen, which under the influence of various activators is 10 converted to plasmin, a proteolytic enzyme, the activity of which resembles that of trypsin. Plasmin breaks down fibrinogen and fibrin to fibrin/fibrinogen degradation products.

Under normal conditions, the fibrinolysis system is in balance with the coagulation system. Small thrombi formed in the blood stream are dissolved enzymatically and the circulation through the vessels is restored by the activation of the fibrinolytic system in the 15 body. If the fibrinolytic activity is too high, it may cause or prolong bleeding. The activity can be inhibited by natural inhibitors in the blood.

Prolyl endopeptidase cleaves peptide bonds on the carboxyl side of proline residues within a peptide chain. It is a serine protease which readily degrades a number of neuropeptides including substance P, neuropeptin, thyrotropin-releasing hormone and 20 luteinizing hormone-releasing hormone and which has been associated with the ability of cells to produce interleukin 2 (IL-2). The enzyme is inhibited by benzyloxycarbonyl-prolyl-prolinal with a K_i of 14 nM. Although little is known about the physiological role of prolyl endopeptidase, it may play a prominent role in the regulation of the biological activities of various neuropeptides.

25 The Ig A proteinase-catalyzed cleavage of Ig A, the predominant form of antibody which comprises the first line of defence against infection, separates the Fc from the antigen-binding Fab regions of the molecule. Such cleavage would be expected to impair or abolish its antimicrobial activity. All Ig A proteinases identified thus far cleave after a proline residue within the hinge region of human Ig A. Peptide prolyl-boronic acids inhibit 30 Ig A 1 proteinases from Neisseria gonorrhoea and Hemophilus influenzae indicating these

enzymes belong to the serine protease family of proteolytic enzymes.

The multiple roles played by thrombin in a variety of physiological processes which have been associated with pathological disorders such as cancer, inflammation and neuronal activity, suggest a potential use of thrombin inhibitors in several indications not strictly 5 related to the cardiovascular system.

Many tumor cells have been shown to elicit procoagulant activity associated with the generation of thrombin. As a consequence, local fibrin deposition and coagulation occur which are thought to be important for tumor growth. Additionally, due to its effects on endothelial cells, thrombin may facilitate the extravasation of tumor cells during metastasis. 10 Hence, thrombin inhibitors may prove beneficial not only in the treatment of certain cancers but also in reducing the hypercoagulability frequently observed in patients during therapy with chemotherapeutic agents.

Thrombin activation of endothelial cells induces a number of pro-inflammatory changes such as synthesis and release of interleukin-1, prostaglandins and platelet-activating 15 factor. Additionally, thrombin induces the exposure of CD62 (alternatively known as GMP-140) and CD63, two adhesion molecules responsible for the adhesion of leukocytes to the endothelial surface. Thrombin also increases vascular permeability of proteins involving neutrophils, and cleaves the interleukin-8-precursor protein, a peptide believed to be involved in respiratory disorders, rheumatoid arthritis and ulcerative colitis.

20 Thrombin's involvement in all these pro-inflammatory processes make thrombin inhibitors a potential target for use in the therapeutic treatment of inflammation-related pathological disorders.

The activity of the protease nexin-1, a modulator of nerve growth and a specific natural thrombin antagonist, is markedly and specifically decreased in patients with 25 Alzheimer's disease. This, together with the observation that thrombin-like activity was increased in the brains of Alzheimer's patients, suggests that thrombin inhibitors may have potential for limiting or reversing neuronal pathological changes associated with hyperactivity of thrombin or related serine proteases.

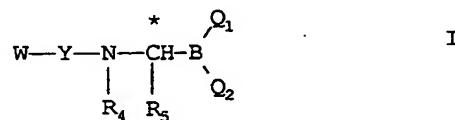
Boronic acids have been studied as inhibitors of various serine esterases and proteases. The first boronic acid-containing amino acid analog to be used as a protease inhibitor was the boronic acid analog of N-acetyl L-phenylalanine, which was used as an inhibitor of chymotrypsin and subtilisin. Peptide boronic acids have been used as inhibitors 5 of chymotrypsin, subtilisin, and elastases.

The interaction of boronic acids with proteases in biological systems is known and various simple boronic acids have been shown to be sufficiently non-toxic for use in humans. Peptide boronic acid inhibitors of elastase have recently been used in animal trials in relation to emphysema. Unlike the peptide chloromethylketones, there was no toxicity 10 reported at biologically effective dosage levels.

European Patent Application 293 881 (Dupont) describes the preparation of peptides comprising C-terminal boronic acid derivatives of lysine, ornithine and arginine, and their use as inhibitors of trypsin-like serine proteases. The other amino acids of the peptides are all either the D- or the L- forms of the 20 naturally-occurring amino acids.

15 It has now been found that compounds, having superior properties as inhibitors of trypsin-like serine proteases, are obtained when the peptide contains at least one unnatural α -amino acid having a hydrophobic side chain.

Accordingly, the present invention provides compounds of formula I and salts thereof



wherein W = H or an N-protecting group;

20 Y is a sequence of n amino acids selected such that the n+1 amino acid peptide Y-Lys or Y-Arg has an affinity for the active site of a trypsin-like protease, where n is an integer from 1 to 10 preferably 1 to 4, and in which at least one amino acid is an unnatural amino acid having a hydrophobic side chain;

25 Q₁ and Q₂, which may be the same or different, are selected from -OH, -COR₁, -CONR₁R₂, -NR₁R₂, and -OR₃, or Q₁ and Q₂ taken together form a diol residue; R₁, R₂ and R₃, which

may be the same or different, are C_{1-10} alkyl, C_{6-10} aryl, C_{6-10} aralkyl, or phenyl substituted by up to three groups selected from C_{1-4} alkyl, halogen and C_{1-4} alkoxy;

R_4 is hydrogen or C_{1-10} alkyl;

R_5 is a group -A-X

5 wherein A is $-(CH_2)_z-$ in which z is 2,3,4 or 5; $-CH(CH_3)-(CH_2)_2-$;
 $-CH_2-CH(CH_3)-CH_2-$; $-(CH_2)_2-CH(CH_3)-$; $-(CH_2)_2-C(CH_3)_2-$; $-CH(CH_3)-(CH_2)_3-$;
 $-CH_2-CH(CH_3)-(CH_2)_2-$; $-CH_2-CH_2-CH(CH_3)-CH_2$; $-(CH_2)_2C(CH_3)_2-CH_2-$;
 $(CH_2)_3-CH(CH_3)-$; $-(CH_2)_3-C(CH_3)_2$; $-(CH_2)_3CH(CH_3)CH_2-$; C_{6-10} aryl, C_{6-10} aralkyl

and wherein X is OH, SH, NR_6R_7 or phenyl,

10 wherein R_6 is H or C_{1-10} alkyl, and R_7 is C_{1-10} alkyl, $-CO-R_8$, $CS-R_8$, or SO_2-R_8
 wherein R_8 is H or C_{1-10} alkyl, C_{1-10} alkoxy, C_{6-10} aryl, C_{6-10} aralkyl
 optionally substituted by up to three groups selected from halogen, OH, C_{1-4} alkoxy,
 $C(NH)R_9$, $NR_{10}R_{11}$ and $C(O)OR_6$ (wherein R_6 is as defined above),
 wherein R_9 is C_{1-3} alkyl or $N(CH_3)_2$ and wherein R_{10} and R_{11} (which may be
15 the same or different) are H or C_{1-10} alkyl,

and the asymmetric carbon atom marked * may have the D- or L-configuration, and the compounds may comprise any mixture of these.

By an unnatural amino acid is meant any amino acid other than D- or L- Ala, Arg, Asp, Cys, Gln, Glu, Gly, His, Ile, Leu, Lys, Met, Phe, Pro, Ser, Thr, Trp, Tyr, or Val.

20 Preferably the N-protecting group W is of formula $H(CH_2CH_2O)_p-$ where p = 3-30;
 $R_{12}CO-$; $R_{13}OCO-$ or $R_{14}SO_2-$
 in which R_{12} is C_{1-6} alkyl or $H(CH_2-O-CH_2)_p$, wherein p is as defined above; R_{13} is
 C_{1-6} alkyl, phenyl, benzyl or naphthyl; and R_{14} is phenyl, naphthyl or C_{1-4} alkylphenyl;
25 of which $R_{13}OCO-$ is particularly preferred. The most preferred protecting groups are those of formula $R_{13}'OCO-$ in which R_{13}' is tert- butyl (designated Boc), and in which R_{13}' is benzyl (designated Z).

Preferably R_5 is R_5' where R_5' is $-(CH_2)_z-X'$, in which X' is OH, phenyl, NH-CO- R_8' , NH-CS- R_8' , $NHSO_2R_8'$ or $NR_{10}'R_{11}'$,

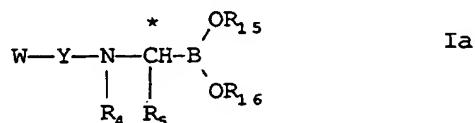
wherein R_8' is H, or C_{1-3} alkyl or C_{1-3} alkoxy and wherein R_{10}' and R_{11}' which may be the same or different are H or C_{1-3} alkyl

5 optionally substituted with up to 3 halogen atoms, and z' is 2,3 or 4.

More preferably R_5 is R_5'' where R_5'' is $-(CH_2)_z-X''$, in which X'' is OH, C_6H_5 , C_6H_4Cl , $C_6H_4N(Me)_2$, NH-CO-CH₃, NH-CHO, NH-CS-NHCH₃, NH-CO-CH(CH₃)₂, NH-CO-CH₂-CH₃, NH-CHS, NH-CO-CH₂Cl, NH-CO-OCH₃ and z' is as defined above.

Preferred compounds are those of formula Ia

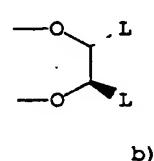
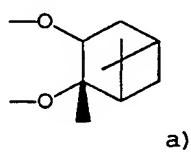
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wherein: W, Y, R_4 and R_5 are as defined above and R_{15} and R_{16} represent the residue of a dihydroxy compound.

Useful examples of dihydroxy compounds are, 2,3-butanediol; catechol; 2,3-dimethyl; 15 2',3'-butandiol; cyclohexanediol; ethylene glycol; 1,2-hexanediol; 2,3-hexanediol; diethanolamine or aliphatic or aromatic compounds having hydroxy groups that are substituted on adjacent carbon atoms or on carbon atoms substituted by another carbon atoms.

Particularly preferred are those compounds in which Q_1 and Q_2 taken together 20 represent the group OPin of formula a) or the group of formula b)



in which L is a C_{1-4} alkyl group, especially methyl, i-Pr, n-Pr or n-Bu.

The amino acids constituting Y are α -amino acids which may be selected from the L-amino acids naturally occurring in proteins, their corresponding enantiomeric D-amino acids or chemically modified alpha-amino acids such as glutamic acid gamma-piperidide 5 (Glu N^γ (Piperidin-1-yl)) or pipecolic acid (Pip), provided that at least one amino acid is an unnatural amino acid having a hydrophobic side chain.

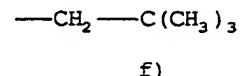
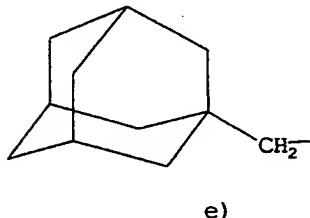
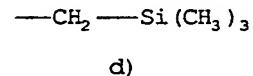
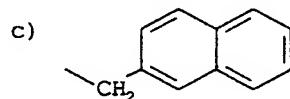
The unnatural amino acid may be an alkylated natural amino acid such as O-alkyl or S-alkyl-cysteine. However, preferred unnatural amino acids are of formula II

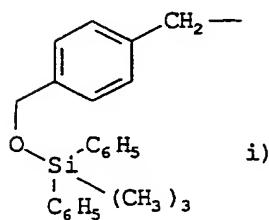
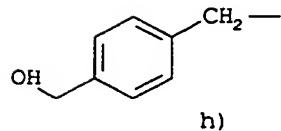
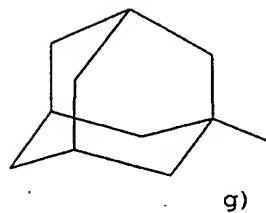
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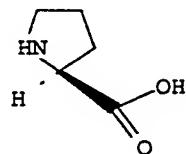
in which R_{17} is a hydrophobic group. Preferred hydrophobic groups consist of a methylene group linked to an aromatic group optionally substituted by a polar group or an alicyclic group having at least two rings and no polar substituents, or to a tert. butyl or trimethylsilyl group. Preferably R_{17} is R_{17}' where R_{17}' is a group of formulae c), d), e), f), g), h) or i)



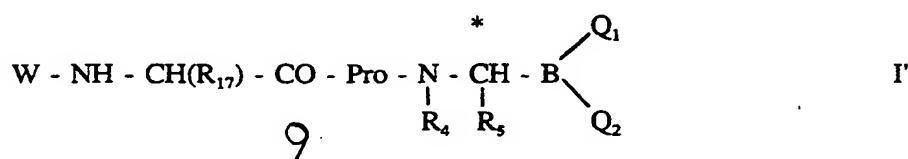


The unnatural amino acids of formula II may be in D- or L- form or any mixture of these, but are preferably in D-form.

More preferred compounds are thrombin inhibitors of formula I in which Y is a sequence of two amino acids, of which the N-terminal amino acid is the unnatural amino acid and
5 the other amino acid is L-proline (Pro), of formula

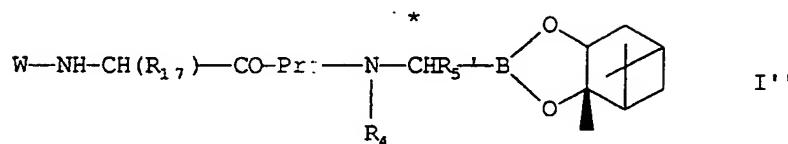


These more preferred compounds have the formula I'



in which W, R₄, R₅, R₁₇, Q₁, and Q₂ are as defined above.

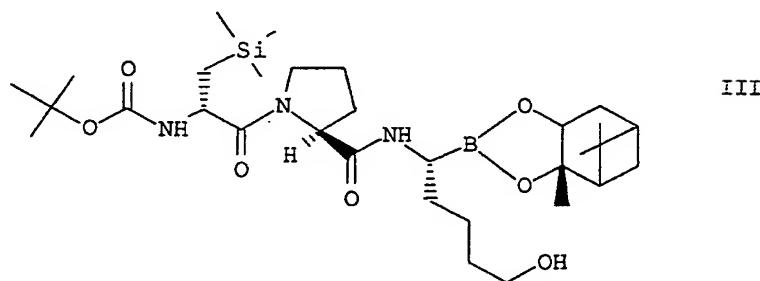
Particularly preferred compounds are those of formula I"



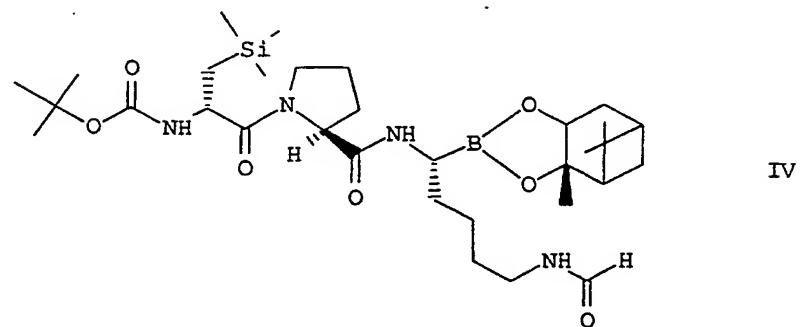
in which W, R₄, R₅' and R₁₇ are as defined above.

The most preferred compounds are the compound of formula III,

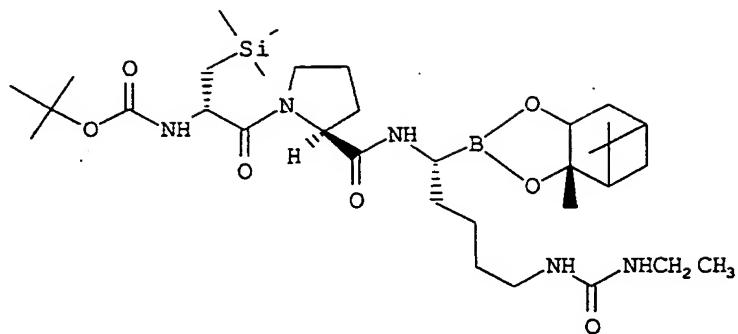
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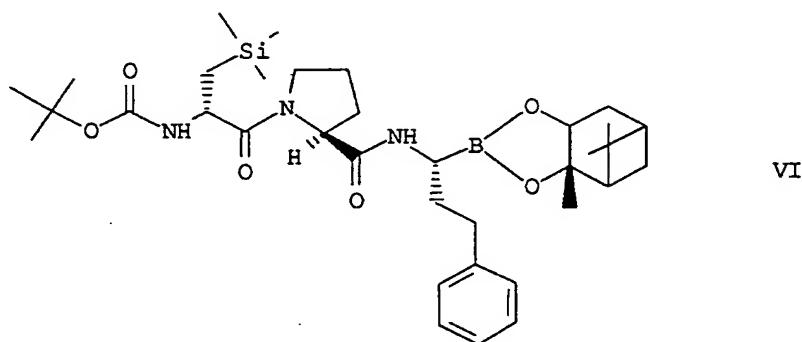
the compound of formula IV,



the compound of formula V



and the compound of formula VI



A peptide is considered to have an affinity for the active site of trypsin-like proteases if the dissociation constant of the peptide-protease complex has a value of 10^{-5} M or lower.

5 The compounds of formula I in which X is NHCHO or NHCOalkyl may be prepared by reacting a compound of formula I in which X is -NH₂ with an active form of the corresponding acid.

10 The compounds of formula I in which X is NHCOalkoxy may be prepared by treating a compound of formula I in which X is -NH₂ with N,O-Bis (trimethylsilyl) acetamide followed by addition of an active form of the corresponding ester.

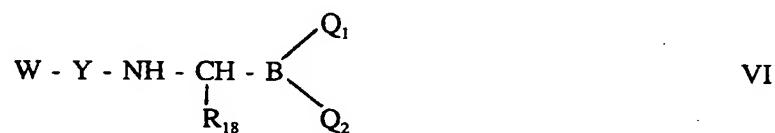
The compounds of formula I in which X is NHC(S)NHalkyl may be prepared by
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reacting a compound of formula I in which X is $-\text{NH}_2$ with the corresponding alkyl isothiocyanate in an organic solvent.

Compounds of formula I in which X is $-\text{NH}_2$ may in turn be produced by hydrogenation of a compound of formula I in which X is $-\text{N}_3$. Hydrogenation may be 5 carried out under standard conditions using for example a Pd/C catalyst.

Compounds of formula I in which X is $-\text{N}_3$ may be produced by reaction of a compound of formula VI

10



in which W, Y, Q_1 and Q_2 are defined above and R_{18} is $-\text{A-Br}$ wherein A is as defined above with sodium azide in a polar aprotic solvent such as dimethyl sulphoxide.

The compounds of formula I in which X is $-\text{NHCHS}$ may be prepared by reacting 15 the compound of formula I in which X is NHCHO with Laweson reagent in an organic solvent such as toluol.

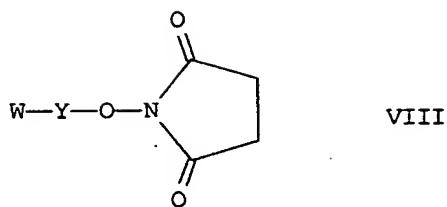
The compounds of formula I in which X is optionally substituted phenyl may be obtained by the reaction of a compound of formula VII

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in which Q_1 and Q_2 are defined above and R_{19} is $-\text{A-phenyl}$ (optionally substituted) wherein A is as defined above, with $\text{LiN}[\text{Si}(\text{CH}_3)_3]_2$ followed by hydrolysis with an excess of acid and coupling with a protected peptide of formula VIII

25



wherein W and Y are as defined above

The reaction is preferably carried out in a dry aprotic polar solvent, for example tetrahydrofuran, at a temperature between -78°C and room temperature.

The intermediates of formula VII may be obtained by the method of Matteson *et al.*

5 Organometallics 3 1284-8 (1984).

The protected peptide of formula VIII may be prepared by methods which are conventional in peptide chemistry, starting from the desired unnatural amino acid. Such amino acids are either commercially available (for example the amino acid in which R₁₆ is the group c) or may be prepared by methods analogous to those described in the literature,
 10 e.g. Angew. Chem. 93, 793 (1981) and J. Am. Chem. Soc. 109, 6881 (1987).

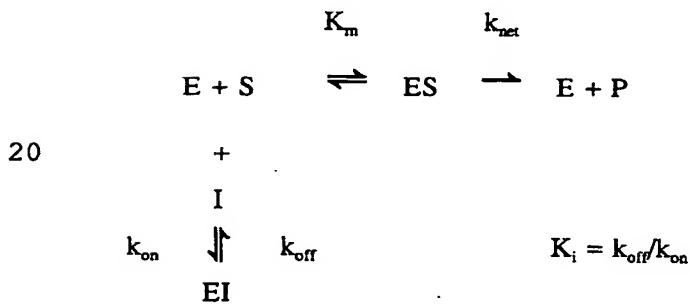
The compounds of formula I in which X is OH may be obtained by reacting a compound of formula I in which X is -OSi(CH₃)₂ C(CH₃)₃ with a desilylating agent, such as tetrabutylammonium-fluoride.

The compounds of formula I are useful as inhibitors of trypsin-like proteases and
 15 may be used in vitro for diagnostic and mechanistic studies of these enzymes. Furthermore, because of their inhibitory action they are indicated for use in the prevention or treatment of diseases caused by an excess of an enzyme in a regulatory system, for example control of coagulation and fibrinolysis.

The compounds of the invention have trypsin-like serine protease inhibiting
 20 properties, as indicated in the following test methods:

a) Enzyme inhibition kinetics

Test substance is dissolved in cremophor/ethanol (1:1) or DMSO and diluted with distilled water to yield a 1 mM stock solution. Further dilutions are made into the assay buffer (100 mM sodium phosphate buffer, pH 7.4, containing 100 mM NaCl and 0.1 % bovine serum albumin). Kinetic assay are performed using a 96-microwell plate; each well contains 50 μ l substrate, 100 μ l test compound and 100 μ l enzyme in buffer. Final concentrations of substrate and enzyme are as follows: 160 pM α -thrombin and 100 μ l Pefachrom TH (K_m = 6.9 μ M), 800 pM human plasmin and 200 μ M Pefachrome PL (K_m = 66.4 μ M), and 260 pM bovine pancreatic trypsin and 500 μ M Pefachrome TRY (K_m = 167.7 μ M). Assays are initiated by adding enzyme to solutions containing the substance to be tested and substrate. The release of p-nitroaniline from the hydrolysis of the substrate is followed for 30 min by measuring the increase in optical density at 405 nm with a Thermomax microwell kinetic reader (Molecular Devices, Menlo Park CA, USA). When the inhibited steady-state rate is achieved rapidly, the inhibition constant (K_i) is determined by fitting the data by weighted linear regression to the Dixon equation (Biochem. J. 1953, 55:170-171). For slow-, tight-binding inhibitors, the mechanism of inhibition may be described by the following scheme:



where E, S, P, and I are the enzyme, substrate, product (p-nitroaniline) and inhibiting substance to be tested, respectively, and k_{on} and k_{off} are the association and dissociation rate constants for the inhibition (Tapparelli *et al.*, J. Biol. Chem., 268 (1993), 4734-4741). Progress-curve data for the formation of p-nitroaniline in the presence of different concentrations of inhibitor are fitted by nonlinear regression to the equation for the mechanism presented in the scheme (Morrison and Walsh, Adv. Enzymol. Relat. Areas

Mol. Biol. 1988, 61:201-301). These analyses yield estimates for the apparent values of k_{on} , k_{off} and K_i which are corrected for the presence of substrate as described by Morrison and Walsh to give the true values. Under the described experimental conditions a K_i of 13 nM is observed for the compound of Example 1.

5 b) In vitro coagulation assays

In vitro coagulation assays are performed with pooled citrated human plasma. Substance to be tested or solvent are incubated with plasma for 10 min at 37°C prior to assay. Thrombin time(TT) determinations are performed at a final thrombin concentration of 5 U/ml. Activated partial thromboplastin time (APTT) is determined 10 by incubating 0.1 ml plasma ± substance to be tested with 0.1 ml purified soya bean phospholipid in ellagic acid (Actin-FS) for 4 min at 37°C and followed by the addition of 0.1 ml $CaCl_2$ (50mM). In this test method, compounds of the invention significantly increase TT and APTT at a concentration of from 0.1 μM to 0.5 μM . With the compound of Example 1, prolongation of TT above 300 sec is achieved at 1.8 μM , 15 elevation of APTT to 2x the control value is achieved at 4.4 μM .

c) In vitro platelet aggregation assay

Washed human platelets are prepared by a modification of the method of Ardlie (Br. J. Pharmacol. 1970, 19:7-17). Washed platelet suspension (0.46 ml) is kept at 37°C and stirred at 1100 rpm. After the addition of the substance to be tested or solvent, the 20 platelets are maintained for 2 min before aggregation is induced by 1 nM human thrombin. The extent of platelet aggregation is quantitated by the maximum aggregation amplitude and inhibition of aggregation rate observed in the absence of inhibitor. In this test method, compounds of the invention significantly inhibit platelet aggregation at a low nM concentration range. The compound of Example 1 has an IC_{50} value of 3.8 nM.

25 Those compounds of the invention which are thrombin or factor Xa inhibitors have anti-thrombogenic properties and may be employed when an anti-thrombogenic agent is needed. Generally, these compounds may be administered orally or parenterally to a host to obtain an anti-thrombogenic effect. In the case of larger mammals such as humans, the

compounds may be administered alone or in combination with pharmaceutical carriers or diluents at a dose of from 0.02 to 15 mg/Kg of body weight and preferably 1-10 mg/Kg to obtain the anti-thrombogenic effect, and may be given as a single dose or in multiple doses or as a sustained release formulation. When an extracorporeal blood loop is to be established for a patient, 0.1-1 mg/Kg may be administered intravenously. For use with whole blood from 1-10 mg per liter may be provided to prevent coagulation. Pharmaceutical diluents are well known and include sugars, starches and water which may be used to make tablets, capsules, injectable solutions and the like. The compounds of the invention may be added to blood for the purpose of preventing coagulation of the blood in blood collection or distribution containers, tubing or implantable devices which come into contact with blood.

In the arterio-venous shunt thrombosis model in the rat, a modification of the model described by Butler et al. (Blood Coag. Fibrinol., Vol. 3, (1992), page 155), the compounds of the invention prevent thrombus formation in a dose dependent manner. Using the compound of Example 1, thrombus formation is inhibited by 21% at a dose of 0.3 mg/kg i.v. and blocked by a dose of 3 mg/kg i.v.

Also, in view of their trypsin-like serine protease inhibition activity, the compounds of formula I are indicated for use for inhibiting vascular remodelling (proliferation, migration) following venous or arterial surgery or other forms of vascular damage.

Percutaneous transluminal coronary angioplasty (PTCA) has become a common surgical procedure for the treatment of atherosclerotic plaques occluding coronary arteries. Angioplasty is also performed, albeit to a lesser extent, on peripheral vessels such as the femoral and renal arteries. The splitting/compression of an atherosclerotic plaque and stretching of the arterial wall during balloon catheter angioplasty additionally results in injury to (or removal of) the endothelial cells and possibly also damage to the underlying smooth muscle cells. This accounts for the primary complications of PTCA, acute reocclusion (build up of an occlusive platelet thrombus on the exposed thrombogenic vessel surface) and chronic restenosis (primarily due to proliferation and migration of smooth muscle cells). Acute restenosis, occurring in ~5% of patients within 24 hours after PTCA, is life threatening and must be surgically dealt with immediately. Chronic restenosis, diagnosed 3-6 months post-surgery in around 30% of patients, leads to chest pain but is

only life threatening if the occlusion is 100% (giving rise to myocardial infarction if the plaque should rupture).

The possible involvement of thrombin in the vascular response to injury has recently come under scrutiny. By its action on platelets, thrombin could be involved in the early 5 platelet recruitment and activation at the site of damage, and by virtue of its mitogenic action on smooth muscle cells, thrombin could also contribute to intimal thickening. Thrombin concentrations are likely to be elevated at sites of vascular injury because of continued activation of the coagulation pathways in the absence of a normal endothelial layer and also due to release of clot-bound thrombin during the thrombolytic process. 10 Additionally, thrombin becomes bound to the extracellular matrix where it can remain active, and protected from the inhibitory effect of circulating antithrombins, for prolonged periods.

The interaction of platelets with a severely injured vessel wall appears in part to be dependent on local thrombin generation.

15 Whilst the accumulated evidence points to thrombin inhibition being a potentially attractive principle to limit restenosis following balloon angioplasty, available agents all have the disadvantage of needing to be administered parenterally (or locally) in order to obtain sufficient local concentrations to demonstrate an effect, or other side effects may be limiting.

20 The compounds of the invention may be used to inhibit vascular remodelling at doses similar to those at which they are used as anti-thrombogenic agents.

Advantageously the compounds of the invention are orally active, have rapid onset of activity and low toxicity. In addition, these compounds may have particular utility in the treatment of individuals who are hypersensitive to compounds such as 25 heparin.

In the following examples, the symbols have the following meanings:

	Z	= benzyloxycarbonyl
	Boc	= t-butyloxycarbonyl
	Ac	= acetyl
5	MeOH	= methyl alcohol
	EtOAc	= ethyl acetate
	DMF	= dimethyl formamide
	DCC	= dicyclohexylcarbodiimide
	HONSu	= N-hydroxy-succinimide
10	OPin	= pinanediol
	THF	= tetrahydrofuran
	n-Bu	= <u>n</u> -butyl
	Np	= p-nitrophenyl
	TLC	= thin layer chromatography
15	Bzl	= benzyl
	TMSal	= trimethylsilylalanine
	BoroPro-OPin	= analog of proline in which the -C00H group is replaced by B-OPin
	BoroLys	= -NH-CH-(CH ₂ -CH ₂ -CH ₂ -CH ₂ -NH ₂)B-

Example 1Boc-D-TMSal-Pro-NH-CH[(CH₂)₄OH]B-OPinA. Boc-D-TMSal-OH

21.5 g (113.7 mmol) D-TMSal ethyl ester, prepared according to the procedure given in Angew. Chem. 93, 793 (1981), is dissolved in CH₂Cl₂ and a solution of an excess of Boc₂O in CH₂Cl₂ is added. After 15 h at room temperature, 500 ml of ice-cold 0.25 N hydrochloric acid is added. The organic layer is washed with 5 % NaHCO₃ and brine, then dried over Na₂SO₄ and concentrated in vacuo.

The crude material (colourless oil) is used directly in the saponification step. It is dissolved in methanol, cooled to 0°C, mixed with 510 ml of 1 N NaOH and stirred at 0°C for 3 h. After acidification to pH 1 with 1 N HCl the mixture is extracted several times with ether. The organic layers are combined, washed with brine, dried over Na₂SO₄ and concentrated in vacuo. The product (29.7 g oil) is used in the next step without further purification.

15 B. Boc-D-TMSal-Pro-ONSu

29.7 g (113.7 mmol) Boc-D-TMSal-OH and 19.0 g (136.3 mmol) p-nitrophenol are dissolved in EtOAc. After cooling to 0°C, 23.4 g (113.6 mmol) DCC is added and the mixture is stirred for 1 h at 0°C and then for 15 h at room temperature. The precipitate is filtered off and washed with EtOAc and the filtrate is concentrated in vacuo. The resulting oil is purified by flash chromatography (9:1, hexane/EtOAc) to give the desired Boc-D-TMSal-ONp as white crystals.

51.6 g (113.7 mmol) Boc-D-TMSal-ONp is dissolved in THF and an aqueous solution of equimolar amounts of proline and Et₃N is added. After 20 h at room temperature, the THF is removed in vacuo and the aqueous residue is diluted with water and then extracted several times with EtOAc. The pH of the aqueous layer is adjusted to 3 by adding 10 % citric acid. The resulting oily product is extracted several times with EtOAc. The combined organic layers are washed with brine, dried over Na₂SO₄ and

concentrated in vacuo. The colourless oil is recrystallized from ether/hexane to give the dipeptide Boc-D-TMSal-Pro-OH as a white crystalline compound, mp: 176°C.

26.0 g (72.5 mmol) of the resulting dipeptide is dissolved in EtOAc. After cooling to 0°C, 9.8 g (85.5 mmol) HONSu and 14.9 g (72.3 mmol) DCC are added. The 5 mixture is stirred for 3 h at 0°C and then for an additional 15 h at room temperature. The mixture is recooled to 0°C, the dicyclohexylurea is filtered off and washed several times with EtOAc. The filtrate is washed with aqueous 0.1 M Na₂CO₃ and then with aqueous 2 % KHSO₄. After drying over Na₂SO₄ and concentration in vacuo, Boc-D-TMSal-Pro-ONSu is obtained as a white foam.

10 C. (+)-Pinanediol-(S)-1-chloro-5-t-butyldimethylsiloxy-pentane-1-boronate

10.5 ml (120 mmol) 3-Butene-1-ol, 22.3 g (144 mmol) *t*-butyldimethylsilylchloride and 20.4 g (300 mmol) imidazole are dissolved in 60 ml DMF and stirred overnight at 35°C. The two layers are separated and the product layer is washed with 2 N tartaric acid, water and brine. After drying over Na₂SO₄ and 15 concentration in vacuo, 1-*t*-butyldimethylsiloxy-3-butene is obtained as colourless oil.

7.45 g (40 mmol) of this product is stirred for 24 h with 5.1 g (40 mmol) catecholborane at 125°C, yielding a yellow-brown oil. This oil is added to 6.9 g (40 mmol) (+)-pinanediol in 30 ml THF and stirred overnight. After flash chromatography (95:9, hexane/EtOAc) (+)-pinanediol-4-*t*-butyldimethylsiloxy-butane-1-boronate is 20 obtained.

Over a 20 min period 17 ml (27.0 mmol) BuLi (1.6 M in hexane) is added to a precooled (-100°C) solution of 2.8 ml CH₂Cl₂ and 49 ml THF. After stirring for 15 min at 100°C, 9.0 g (24.5 mmol) of the pinanediolboronate product obtained above in 24 ml THF is added over a 20 min period. The reaction mixture is again stirred for 15 min at 25 100°C, after which 1.24 g (12.3 mmol) ZnCl₂ (solid) is added. The reaction mixture is allowed to warm up to room temperature overnight. After concentration in vacuo the residue is dissolved in ether/H₂O. The organic layer is dried over Na₂SO₄ and concentrated in vacuo. (+)-pinanediol-(S)-1-chloro-5-*t*-butyldimethylsiloxy-butane-1-

boronate is obtained as yellow-orange oil.

D. Boc-D-TMSal-Pro-NH-CH[(CH₂)₂OSi(t-Bu)Me₂]B-OPin

12.8 ml (20.4 mmol) Butyllithium (1.6 M in hexane) is added to a precooled (-78°C) solution of 4.3 ml (20.4 mmol) hexamethyldisilazane in 30 ml THF. The reaction 5 mixture is stirred for 1 h at room temperature, then cooled down to -78°C again. 8.5 g (20.4 mmol) (+)-pinanediol-(S)-1-chloro-5-*t*-butyldimethylsiloxy-butane-1-boronate in THF is added. After stirring for 1 h at -78°C, the solution is allowed to warm overnight to room temperature. After recooling to -78°C 3 mol equivalents of HCl in dioxane are added. The mixture is stirred for 1 h at -78°C, then for 2 h at room temperature. After 10 cooling down to -20°C, a solution of 9.28 g (40.8 mmol) of the active ester of Example 1, step B in CH₂Cl₂ is added, followed by the addition of 5.67 ml (40.8 mmol) triethylamine. The mixture is stirred for 1 h at -20°C and for 2 h at room temperature, then filtered. After concentration in vacuo, the residue is dissolved in ether/H₂O. The organic layer is dried over Na₂SO₄ and concentrated in vacuo. After flash 15 chromatography (6:4, hexane/EtOAc), the desired product is obtained; [α]_D²⁰ = - 45.6° (c = 0.5 in MeOH); MH⁺ = 736.

E. Boc-D-TMSal-Pro-NH-CH[(CH₂)₂OH]B-OPin

600 mg (0.816 mmol) of the siloxy compound obtained in step D of Example 1 is dissolved in THF and 514 mg (1.62 mmol) tetrabutylammonium fluoride is added. After 20 stirring overnight at ambient temperature, the mixture is concentrated in vacuo and dissolved in ether/H₂O. The organic layer is dried over Na₂SO₄ and concentrated in vacuo. The side product is removed with EtOAc on silicagel, then the product is eluted with EtOAc/EtOH (9:1), yielding the title product as a white foam; [α]_D²⁰ = - 72.4° (c = 0.5 in MeOH); MH⁺ = 622.

25 Example 2-4

Boc-D-TMSal-Pro-NH-CH[(CH₂)₂NHCHO]B-OPin

A) (+) Pinanediol-(S)-1-chloro-5-bromo-pentane-1-boronate

20.8 ml (203.3 mmol) 4-Bromo-1-butene is reacted with 924.4 g (203.3 mmol) catecholborane at 100°C over 16 h. The crude product is distilled in vacuo to give 4-bromo-butane-1-boronate as a white crystalline product.

5 27.7 g (163 mmol) (+)-Pinandiol is dissolved in THF and 41.6 g (163 mmol) of 4-bromo-butane-1-boronate as synthesized above is added. After 1 h at room temperature, the THF is removed in vacuo and the residue is purified by flash chromatography (9:1, hexane/EtOAc) to give (+)-pinanediol-4-bromo-butane-1-boronate as a colourless oil.

10 The desired (+)-pinanediol-(S)-1-chloro-5-bromo-pentane-1-boronate is prepared according to the procedure given in Organometallics 3, 1284 (1984). 9.8 ml CH₂Cl₂ in THF is cooled to -100°C and 71.6 ml (114.5 mmol) n-butyllithium (1.6 M in hexane) is added over 20 min. After 15 min at -100°C, a cold (-78°C) solution of 32.8 g (104.1 mmol) (+)-pinanediol-5-bromo-pentane-1-boronate in THF is added. After an additional 1 h at -100°C, 7.1 g (52.0 mmol) anhydrous ZnCl₂ in THF is added. After an additional 15 min at -100°C, the reaction mixture is warmed to room temperature. The solvent is removed in vacuo, the residue diluted with hexane/water and extracted several times with hexane. After drying over Na₂SO₄ and removal of the solvent in vacuo, (+)-pinanediol-(S)-1-chloro-5-bromo-pentane-1-boronate is obtained as a yellow oil which is used directly in the next step without further purification.

15 20 B) Boc-D-TMSal-Pro-NH-CH[(CH₂)₄Br]B-OPin

A solution of 65.2 ml (66.2 mmol) LiN(SiMe₃)₂ (1 M in THF) in THF is cooled to -78°C. 23.7 g (65.2 mmol) α-Chloro-boronate of Example 2, step A in THF is added. After stirring for 1 h at -78°C, the mixture is stirred for 15 h at room temperature.

25 After this period, the reaction mixture is recooled to -78°C. 29.8 ml (6.56 N solution, 196 mmol) HCl in dioxane is added and the solution stirred for 45 min at -78°C and then for 2 h at room temperature. The mixture is cooled to -15°C, 29.7 g (65.2 mmol) Boc-TMSal-Pro-ONSu of Example 1, step B in CH₂Cl₂ is added, followed

by 18.1 ml (130.4 mmol) triethylamine to start the coupling reaction. After stirring at -15°C for 1 h, the mixture is stirred for 2 h at room temperature. The mixture is then filtered over Hyflo and concentrated in vacuo. The residue is diluted with ether/water and extracted several times with ether. After drying over Na_2SO_4 and concentration in vacuo, the desired Boc-D-TMSal-Pro-NH-CH $[(\text{CH}_2)_4\text{Br}]$ B-OPin is obtained as white crystals from ether/hexane, mp: 74°C.

C) Boc-D-TMSal-Pro-NH-CH $[(\text{CH}_2)_4\text{N}_3]$ B-OPin

33.3 g (48.6 mmol) of the product of Example 2, step B is dissolved in DMSO and 6.3 g (97.2 mmol) sodium azide is added. The mixture is stirred for 6 h at room temperature. Ether/ice water is added, and the resulting oil is crystallized to give Boc-D-TMSal-Pro-NH-CH $[(\text{CH}_2)_4\text{N}_3]$ B-OPin as a white crystalline compound, mp: 69-70°C; $[\alpha]_D^{20} = -56.6^\circ$ (c = 1.0 in MeOH); $\text{MH}^+ = 647$.

D) Boc-D-TMSal-Pro-BoroLys-OPin

22.0 g (34.0 mmol) of the azide of Example 2, step C is dissolved in EtOAc and hydrogenated in the presence of 4.0 g of 10% Pd/C. After 9 h, the catalyst is removed and the solution is concentrated in vacuo. The resulting foam is dissolved in EtOAc and crystallized to give the desired Boc-TMSal-Pro-BoroLys-OPin as white crystals. mp: 128-129°C; $[\alpha]_D^{20} = -40.8^\circ$ (c = 0.5 in CH_2Cl_2); $\text{MH}^+ = 621$.

E) Boc-D-TMSal-Pro-NH-CH $[(\text{CH}_2)_4\text{NHCHO}]$ B-OPin

20 0.224 ml (5.95 mmol) Formic acid and 0.530 g (5.2 mmol) acetic anhydride are stirred 2 h at 60°C. The mixture is cooled to 0°C and 1.86 g (3.00 mmol) of the borolysine obtained in step D of Example 2 dissolved in THF is added. After 10 min stirring at 0°C, the reaction mixture is stirred at room temperature overnight. 80 ml of icewater is added, the solution extracted several times with ether and washed with brine. 25 After drying over Na_2SO_4 and concentration in vacuo, the desired product is obtained as a white foam which can be crystallized from ether/hexane; mp: 93-99°C; $[\alpha]_D^{20} = -77.8^\circ$ (c = 0.5 in MeOH); $\text{MH}^+ = 649$.

The Boc-D-TMSal-Pro-NH-CH[(CH₂)₅NHCHO]B-OPin ($[\alpha]_D^{20} = -47.2^\circ$ (c = 0.5 in MeOH); MH⁺ = 663) and Boc-D-TMSal-Pro-NH-CH[(CH₂)₃NHCHO]B-OPin ($[\alpha]_D^{20} = -68.0^\circ$ (c = 0.5 in MeOH); MH⁺ = 635) products are obtained analogously.

Example 5-14

5 Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHC(O)CH₃]B-OPin

20 μ l (0.25 mmol) Pyridine and 18 μ l (0.25 mmol) acetyl chloride in CH₂Cl₂ are cooled to 0°C, 155.2 mg (0.25 mmol) of the borolysine product of Example 2, step D is added and the solution is stirred for 1 h. Water is added, the product extracted several times with ether, washed with brine, dried over Na₂SO₄ and concentrated in vacuo. The 10 desired product is obtained as an oil; $[\alpha]_D^{20} = -62.6^\circ$ (c = 0.5 in MeOH); MH⁺ = 663.

The following (Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHC(O)R]B-OPin) products wherein R is as indicated in the table below are prepared analogously from the corresponding acyl chlorides or bromides:

	Ex.	R	$[\alpha]_D^{20}$ (c = 0.5 in MeOH)	MH ⁺
15	6	Et	- 55.8°	667
	7	i-Pr	- 60.2°	691
	8	CH ₂ F	- 58.8°	681
	9	CH ₂ Br	- 58.8°	741
	10	CH ₂ OMe	- 79.8°	693
	11	CO ₂ Me	- 64.8°	707
	12	CO ₂ Et	- 59.6 °	721
	13	NMe ₂	- 64.2°	692
	14	OCH ₂ Cl	- 62.0°	713

Example 15-16Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHC(O)CH₂Cl]B-OPin

124.2 mg (0.2 mmol) of the borolysine product of Example 2, step D in THF is cooled to 0°C and 35.2 mg (0.2 mmol) monochloroacetic anhydrid is added. After 5 stirring for 3 h at room temperature, the solvent is removed in vacuo and the product is obtained as a white foam; $[\alpha]_D^{20} = -57.8^\circ$ (c = 0.5 in MeOH); $MH^+ = 697$.

The Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHC(O)CCl₃]B-OPin product is prepared analogously; $[\alpha]_D^{20} = -54.0^\circ$ (c = 0.5 in MeOH); $MH^+ = 765$.

Example 1710 Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHC(O)OCH₃]B-OPin

58.7 μ l (0.24 mmol) N,O-Bis(trimethylsilyl)acetamide in CH₂Cl₂ is added to 124.2 mg (0.20 mmol) of the borolysine product of Example 2, step D in CH₂Cl₂ and stirred for 1 h at room temperature. After cooling to 0°C, 19.5 μ l (0.24 mmol) methyl chloroformate in CH₂Cl₂ is added and the mixture stirred for 5 h at 0°C. The CH₂Cl₂ is 15 removed and pH 7 buffer is added at 0°C. The product is extracted several times with ether, washed with brine, dried over Na₂SO₄ and concentrated in vacuo, yielding a white foam; $[\alpha]_D^{20} = -59.6^\circ$ (c = 0.5 in MeOH); $MH^+ = 679$.

Example 18-22Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHC(S)NHCH₃]B-OPin

20 124.2 mg (0.2 mmol) of the borolysine product of example 2, step D in CH₂Cl₂ is cooled to 0°C and 15 mg (0.2 mmol) methyl isothiocyanate is added. After stirring 7 h at room temperature, the solvent is removed in vacuo and the product is obtained as a white foam, which can be crystallized from ether/hexane; mp: 109-113°C; $[\alpha]_D^{20} = -66.8^\circ$ (c = 0.5 in MeOH); $MH^+ = 694$.

Analogously Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHC(S)NHEt]B-OPin ([α]_D²⁰ = - 66.4° (c = 0.5 in MeOH); MH⁺ = 708), Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHC(O)NHCH₃]B-OPin ([α]_D²⁰ = - 62.2° (c = 0.5 in MeOH); MH⁺ = 678), Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHC(O)-NHEt]B-OPin ([α]_D²⁰ = - 65.6° (c = 0.5 in MeOH); MH⁺ = 692) and Boc-D-TMSal-Pro-NH-CH[(CH₂)₃NHC(O)NHEt]B-OPin ([α]_D²⁰ = - 71.0° (c = 0.5 in MeOH); MH⁺ = 678), are obtained from the corresponding iso(thio)cyanates.

Example 23

Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHCH₃]B-OPin

10 217 mg (0.35 mmol) of the formamide product of Example 2, step E in toluene is treated with 70.8 mg (0.175 mmol) Laweson-Reagent. After stirring for 1.5 h at room temperature, toluene is removed in vacuo. The desired product is crystallized from ether; mp: 123-125°C; [α]_D²⁰ = - 74.8° (c = 0.5 in MeOH); MH⁺ = 665.

Example 24

Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHC(S)CH₃]B-OPin

124 mg (0.2 mmol) of the borolysine product of Example 2, step D is dissolved in MeOH and 23 μ l (0.2 mmol) ethyl dithioacetate in MeOH is added at room temperature. After stirring for 2.5 h at 60°C, the solvent is removed in vacuo. The residue is purified by RP-chromatography (7:3, EtOH/H₂O) and the desired product is obtained as a white foam; [α]_D²⁰ = - 65.8° (c = 0.5 in MeOH); MH⁺ = 679.

Example 25-26

Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHC(O)NH₂]B-OPin

248.3 mg (0.4 mmol) of the borolysine product of Example 2, step D and 0.4 ml 1 N HCl in H₂O is warmed to 50°C. After 5 min, 33.2 mg (0.4 mmol) of potassium cyanate is added in small portions. After 6 h at 50°C water is added, the product

extracted with EtOAc, dried over Na_2SO_4 and concentrated in vacuo. After flash chromatography (1:9, hexane/EtOAc), the desired product is obtained; $[\alpha]_D^{20} = -71.7^\circ$ (c = 0.5 in MeOH); $\text{MH}^+ = 664$.

5 The Boc-D-TMSal-Pro-NH-CH[(CH₂)₃NHC(O)NH₂]B-OPin product is prepared analogously; $[\alpha]_D^{20} = -54.0^\circ$ (c = 0.5 in MeOH); $\text{MH}^+ = 765$.

Example 27

Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHC(O)CH₂OH]B-OPin

10 48 μl (0.6 mmol) pyridine and 99.6 μl (0.6 mmol) benzyloxyacetyl chloride in THF are cooled to 0°C and 372.4 mg (0.6 mmol) of the borolysine product of Example 2, step D is added. After 3 h at 0°C, water is added, the product extracted several times with ether, dried over Na_2SO_4 and concentrated in vacuo.

15 The resulting white foam (370 mg, 0.48 mmol) is dissolved in EtOH and hydrogenated in the presence of 0.5 g of 10% Pd/C at 40 psi. After 12 h, the catalyst is removed and the solution is concentrated in vacuo. After flash chromatography (9:1, EtOAc/EtOH), the desired product is obtained; $[\alpha]_D^{20} = -67.0^\circ$ (c = 0.5 in MeOH); $\text{MH}^+ = 679$.

Example 28

Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHSO₂CH₃]B-OPin

20 19.8 μl (0.25 mmol) methane sulfonic acid chloride in THF at 0°C is added to 20 μl (0.25 mmol) pyridine. 155.2 mg (0.25 mmol) of the borolysine product of Example 2, step D in THF is added to this mixture. After stirring for 2.5 h at 0°C, water is added, the product extracted with ether, dried over Na_2SO_4 and concentrated in vacuo, yielding the product as a white foam; $[\alpha]_D^{20} = -61.6^\circ$ (c = 0.5 in MeOH); $\text{MH}^+ = 699$.

Example 29-31Boc-D-TMSal-Pro-NH-CH[(CH₂)₂C₆H₅]B-OPinA. (+)-Pinanediol-(S)-1-chloro-3-phenyl-propane-1-boronate

3.47 g (30.0 mmol) Styrene and 3.6 g (30.0 mmol) catecholborane are stirred for 5 20 h at 100°C, yielding a yellow-brown oil. This oil is added to 5.0 g (30.0 mmol) (+)-pinanediol in THF and stirred overnight. After flash chromatography (8:2, hexane/EtOAc) (+)-pinanediol-2-phenyl-ethane-1-boronate is obtained.

Over a 20 min period 15 ml (24.0 mmol) BuLi (1.6 M in hexane) are added to a precooled (-100°C) solution of 2.1 ml CH₂Cl₂ and 37 ml THF. After stirring for 30 min 10 at -100°C, 6.2 g (21.8 mmol) of the pinanediolboronate product obtained above in THF is added over a 20 min period. The reaction mixture is again stirred for 1 h at -100°C, after which 1.51 g (10.9 mmol) ZnCl₂ in THF is added. The reaction mixture is allowed to warm up to room temperature overnight. After concentration in vacuo the residue is dissolved in ether/H₂O. The organic layer is dried over Na₂SO₄ and concentrated in 15 vacuo. (+)-pinanediol-(S)-1-chloro-3-phenyl-propane-1-boronate is obtained as yellow-orange oil.

B. Boc-D-TMSal-Pro-NH-CH[(CH₂)₂C₆H₅]B-OPin

5.1 ml (8.09 mmol) Butyllithium (1.6 M in hexane) is added to a precooled (-78°C) solution of 1.7 ml (8.09 mmol) hexamethyldisilazane in THF. The reaction 20 mixture is stirred 1 h at room temperature, then cooled down to -78°C again. 2.68 g (8.09 mmol) (+)-pinanediol-(S)-1-chloro-3-phenyl-propane-1-boronate dissolved in THF is added. After stirring for 1 h at -78°C, the solution is warmed up overnight to room temperature. After recooling to -78°C 3 mol equivalents of HCl in dioxane are added. The mixture is stirred for 1 h at -78°C, then for 2 h at room temperature. After cooling 25 down to -20°C, a solution of 3.7 g (8.09 mmol) of the active ester of Example 1, step B in CH₂Cl₂ is added, followed by the addition of 2.3 ml (18.2 mmol) triethylamine. The mixture is stirred for 1 h at -20°C and for 2 h at room temperature, then filtered. After concentration in vacuo, the residue is dissolved in ether/H₂O. The organic layer is dried

over Na_2SO_4 and concentrated in vacuo. After flash chromatography (6:4, hexane/EtOAc), the desired product is obtained; $[\alpha]_D^{20} = -88.6^\circ$ (c = 0.5 in MeOH); $\text{MH}^+ = 654$.

The Boc-D-TMSal-Pro-NH-CH $[(\text{CH}_2)_2(p\text{-Cl-C}_6\text{H}_4)]\text{B-OPin}$ ($[\alpha]_D^{20} = -83.2^\circ$ (c = 0.5 in MeOH); $\text{MH}^+ = 688$) and Boc-D-TMSal-Pro-NH-CH $[(\text{CH}_2)_2(p\text{-NMe}_2\text{-C}_6\text{H}_4)]\text{B-OPin}$ ($[\alpha]_D^{20} = -84.8^\circ$ (c = 0.54 in MeOH); $\text{MH}^+ = 697$) products are obtained analogously.

Example 32



10 A. $\text{CH}_3[\text{O}(\text{CH}_2)_2]_3\text{OCH}_2\text{C}(\text{O})\text{-D-TMSal-Pro-NH-CH}[(\text{CH}_2)_4\text{N}_3]\text{B-OPin}$

5.15 g (8.00 mmol) of the azide product of Example 2, step C is added to 40.0 ml of acetic acid/conc. HCl (9:1) and stirred for 75 min. After concentration in vacuo, HCl-H-D-TMSal-Pro-NH-CH $[(\text{CH}_2)_4\text{N}_3]\text{B-OPin}$ is crystallized from ether; mp: 87°C.

0.29 ml (2.40 mmol) pivaloyl chloride in THF is added to a mixture of 1.17 g 15 (2.00 mmol) of the above obtained product and 0.34 ml (2.40 mmol) triethylamine in THF at 0°C and stirred for 1 h at this temperature. To this solution 533 mg (2.40 mmol) $\text{CH}_3[\text{O}(\text{CH}_2)_2]_3\text{OCH}_2\text{CO}_2\text{H}$ in THF and subsequently 4.0 ml of saturated aqueous NaHSO_4 are added. After stirring for 1 h at room temperature, saturated aqueous NaHSO_4 is added and the product is extracted several times with EtOAc. The organic 20 layers are washed with 2 N H_2SO_4 and brine, dried over Na_2SO_4 and concentrated in vacuo. The crude product is dissolved in MeOH/water (6:4) and washed with hexane. After concentration of the MeOH/water layer, $\text{CH}_3[\text{O}(\text{CH}_2)_2]_3\text{OCH}_2\text{C}(\text{O})\text{-D-TMSal-Pro-NH-CH}[(\text{CH}_2)_4\text{N}_3]\text{B-OPin}$ is obtained as an oil; $[\alpha]_D^{20} = -74.5^\circ$ (c = 0.83 in MeOH); $\text{MH}^+ = 751$.

25 B. $\text{CH}_3[\text{O}(\text{CH}_2)_2]_3\text{OCH}_2\text{C}(\text{O})\text{-D-TMSal-Pro-NH-CH}[(\text{CH}_2)_4\text{NH}_2]\text{B-OPin}$

1.05 g (1.40 mmol) of the product of Example 32, step A is dissolved in 14 ml EtOH and hydrogenated in the presence of 140 mg of 10% Pd/C and 0.84 ml (1.38 mmol) 2 N HCl. After 2.5 h, the catalyst is removed and water is added. The water layer is washed with ether and concentrated in vacuo, yielding 855 mg (80 %)

5 $\text{CH}_3[\text{O}(\text{CH}_2)_2]_3\text{OCH}_2\text{C}(\text{O})\text{-D-TMSal-Pro-NH-CH}[(\text{CH}_2)_4\text{NH}_2]\text{B-OPin}$ as an oil; $[\alpha]_D^{20} = -74.2^\circ$ (c = 0.61 in MeOH); $\text{MH}^+ = 725$.

C. $\text{CH}_3[\text{O}(\text{CH}_2)_2]_3\text{OCH}_2\text{C}(\text{O})\text{-D-TMSal-Pro-NH-CH}[(\text{CH}_2)_4\text{NHCHO}]\text{B-OPin}$

31 μl (0.80 mmol) formic acid and 71 μl (0.70 mmol) acetic anhydrid are stirred for 2 h at 50°C. After cooling to 0°C, 325 mg (0.43 mmol) of the borolysine product of

10 Example 32, step B in THF and 0.12 ml (0.86 mmol) triethylamine is added. After stirring for 17 h at room temperature, EtOAc is added and the solution washed with 2 N H_2SO_4 and brine, dried over Na_2SO_4 and concentrated in vacuo. After RP-chromatography (MeOH/water, gradient 50% $\text{H}_2\text{O} \rightarrow 25\% \text{H}_2\text{O}$), the desired product is obtained as an oil; $[\alpha]_D^{20} = -80.8^\circ$ (c = 0.27 in MeOH); $\text{MH}^+ = 753$.

15 Example 33

$\text{CH}_3[\text{O}(\text{CH}_2)_2]_3\text{OCH}_2\text{C}(\text{O})\text{-D-TMSal-Pro-NH-CH}[(\text{CH}_2)_4\text{NHC(O)NHEt}]\text{B-OPin}$

325 mg (0.43 mmol) of the borolysine product of Example 32, step B in THF is cooled to 0°C and 40 μl (0.43 mmol) ethyl isocyanate and 48 μl (0.43 mmol) N-methyl morpholine is added. After 4 h stirring at room temperature, EtOAc is added and the

20 solution washed with 1 N NaHSO_4 , saturated aqueous NaHCO_3 and brine, dried over Na_2SO_4 and concentrated in vacuo. After RP-chromatography (MeOH/water, gradient 50% $\text{H}_2\text{O} \rightarrow 25\% \text{H}_2\text{O}$), the desired product is obtained as an oil; $[\alpha]_D^{20} = -76.0^\circ$ (c = 0.55 in MeOH); $\text{MH}^+ = 796$.

Example 34

25 $\text{H-D-TMSal-Pro-NH-CH}[(\text{CH}_2)_4\text{NHCHO}]\text{B(OH)}_2$

150 mg (0.231 mmol) of the formamide product of Example 2, step E is

dissolved in 2.5 ml acetic acid/conc. HCl (1:9) and stirred for 4 h at room temperature. After concentration in vacuo, the residue is dissolved 3 times in toluene and again concentrated in vacuo. The desired product is obtained as yellow foam; $[\alpha]_D^{20} = -63.6^\circ$ (c = 0.55 in MeOH); $MH^+ = 415$.

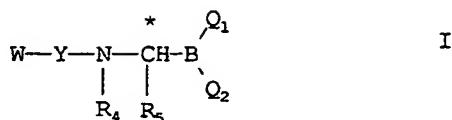
5 Example 35

H-D-TMSal-Pro-NH-CH[(CH₂)₄NHC(O)NHEt]B(OH)₂

150 mg (0.217 mmol) of the Boc-D-TMSal-Pro-NH-CH[(CH₂)₄NHC(O)NHEt]B-OPin product of Example 21 is dissolved in 2.5 ml acetic acid/conc. HCl (1:9) and stirred for 4 h at room temperature. After concentration in vacuo, the residue is dissolved 3 times in toluene and again concentrated in vacuo. The desired product is obtained as orange foam; $[\alpha]_D^{20} = -74.1^\circ$ (c = 0.56 in MeOH); $MH^+ = 458$.

CLAIMS

1. A compound of formula I



wherein: W is hydrogen or an N-protecting group

5 Y is a sequence of n amino acids such that the n+1 amino acid peptide Y-Lys or Y-Arg has an affinity for the active site of a trypsin-like protease; where n is an integer of from 1 to 10 and in which at least one amino acid is an unnatural amino acid having a hydrophobic side chain;

Q₁ and Q₂ are the same or different and are selected from -OH, -COR₁,
 10 -CONR₁R₂, -NR₁R₂ or -OR₃ or Q₁ and Q₂ taken together form a diol residue;

R_1 , R_2 and R_3 which may be the same or different, are C_{1-10} alkyl, C_{6-10} aryl, C_{6-10} aralkyl or phenyl substituted by up to three groups selected from C_{1-4} alkyl, halogen and C_{1-4} alkoxy;

R_4 is hydrogen or C_{1-10} alkyl

15 R_5 is a group -A-X

wherein A is $-(CH_2)_z-$ in which z is 2,3,4 or 5; $-CH(CH_3)-(CH_2)_2-$; $-CH_2-CH(CH_3)-CH_2-$; $-(CH_2)_2-CH(CH_3)-$; $-(CH_2)_2-C(CH_3)_2-$; $-CH(CH_3)-(CH_2)_3-$; $-CH_2-CH(CH_3)-(CH_2)_2-$; $-CH_2-CH_2-CH(CH_3)-CH_2-$; $-(CH_2)_2C(CH_3)_2-CH_2-$; $(CH_2)_3-CH(CH_3)-$; $-(CH_2)_3-C(CH_3)_2-$; $-(CH_2)_3CH(CH_3)CH_2-$; $C_{6-10}\text{aryl}$, $C_{6-10}\text{aralkyl}$

20 and wherein X is OH, SH, NR₆R₇ or phenyl,

wherein R₆ is H or C₁₋₁₀alkyl, and R₇ is C₁₋₁₀alkyl, -CO-R₈, CS-R₈, or SO₂-R₈.

wherein R₈ is H or C₁₋₁₀alkyl, C₁₋₁₀alkoxy, C₆₋₁₀aryl, C₆₋₁₀aralkyl

optionally substituted by up to three groups selected from halogen, OH, C₁₋₄alkoxy,

$C(NH)R_9$, $NR_{10}R_{11}$ and $C(O)OR_6$ (wherein R_6 is as defined above),

wherein R_9 is C_{1-3} alkyl or $N(CH_3)_2$ and wherein R_{10} and R_{11} (which may be the same or different) are H or C_{1-10} alkyl,

and the asymmetric carbon atom marked * may have the D- or L-configuration, and the 5 compounds may comprise any mixture of these.

2. A compound according to claim 1 in which W is $H(CH_2CH_2O)_p^-$, $R_{12}CO^-$, $R_{13}OCO^-$ or $R_{14}SO_2^-$, wherein:

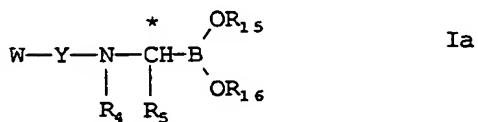
$R_{12} = C_{1-6}$ alkyl or $H(CH_2-O-CH_2)_p$,

$R_{13} = C_{1-6}$ alkyl, phenyl, benzyl or naphthyl; and

10 $R_{14} =$ phenyl, naphthyl or C_{1-4} alkylphenyl

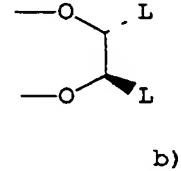
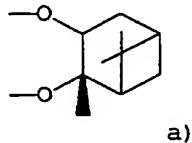
wherein p = 3-30

3. A compound according to claim 1 or 2 which is of formula Ia



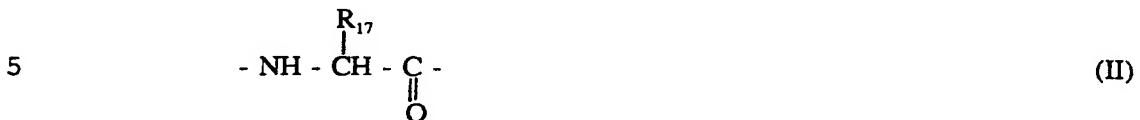
15 wherein: W, Y, R_4 and R_5 are as defined in claims 1 or 2 and R_{15} and R_{16} represent the residue of a dihydroxy compound.

4. A compound according to claim 1 or 2 wherein Q_1 and Q_2 together represent a group of formula (a) or (b)



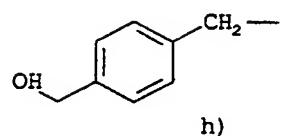
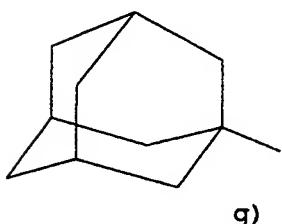
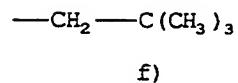
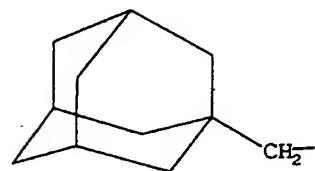
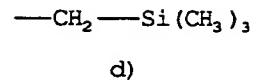
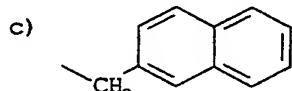
in which L is a C₁₋₄alkyl group.

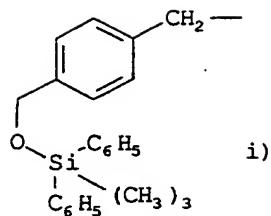
5. A compound according to any one of claims 1 to 4 wherein the unnatural amino acid is of formula II



wherein R₁₇ is a hydrophobic group.

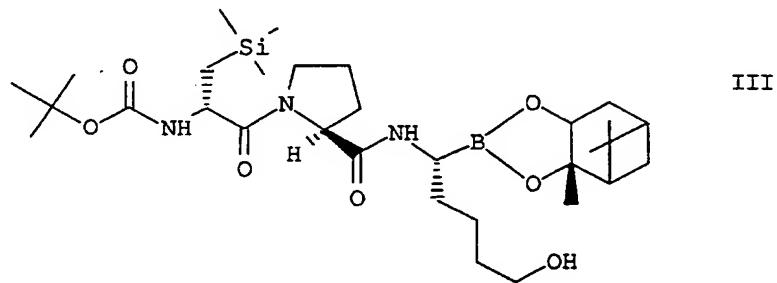
6. A compound according to claim 5 wherein R₁₇ is R₁₇ and is a group of formula
10 (c), (d), (e), (f), (g), (h) or (i)



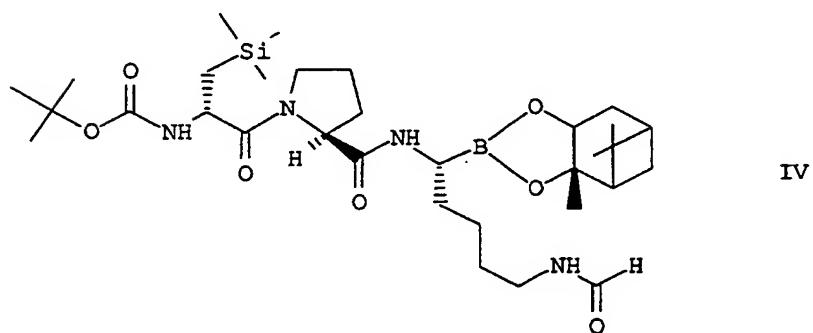


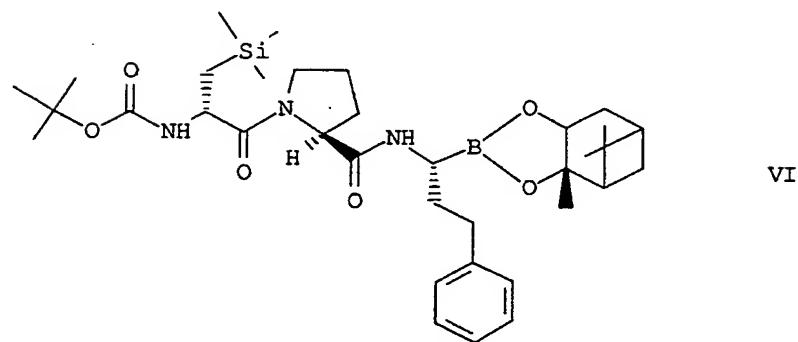
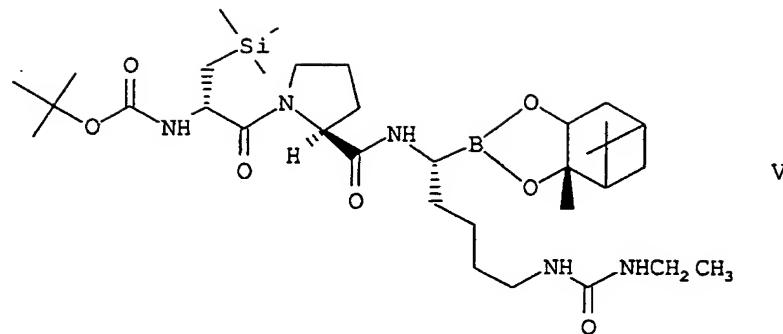
7. A compound according to claim 1 wherein Y is a sequence of two amino acids of which the N-terminal amino acid is the unnatural amino acid and the other amino acid is L-proline.

8. A compound according to claim 1 selected from the compounds of formulae III,
5 IV and VI



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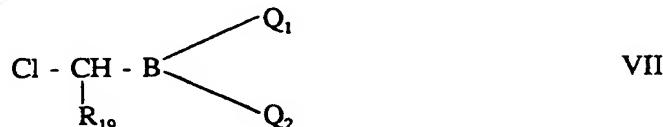


9. A process for the preparation of a compound of formula I as defined in claim 1 which comprises:

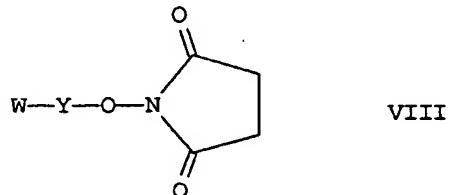
- i) when X is NHCHO or NHCOalkyl, reacting a compound of formula I in which X is -NH₂ with an active form of the corresponding acid;
- 5 ii) when X is NHCOalkoxy, treating the compound of formula I in which X is -NH₂ with N, O -bis (trimethylsilyl) acetamide followed by addition of an active form of the corresponding ester;
- iii) when X is NHC(S)NHalkyl, reacting the compound of formula I in which X is -NH₂ with the corresponding alkyl isothiocyanate;

- iv) when X is NHCHS, reacting the compound of formula I in which X is -NHCHO with Laweson reagent;
- v) when X is optionally substituted phenyl, reacting a compound of formulae VII

5



in which Q1 and Q2 are as defined in claim 1 and R₁₉ is -A-phenyl (optionally substituted) wherein A is as defined in claim 1, with LiN[Si(CH₃)₃]₂, followed by hydrolysis with an excess of acid and coupling with a protected peptide of formula VIII



10

wherein W and Y are as defined in claim 1.

- vi) when X is OH reacting a compound of formula I in which X is -OSi(CH₃)₂-C(CH₃)₃ with a desilylating agent.

10. Use of a compound of any one of claims 1 to 8 as a inhibitor of trypsin like serine proteases.
- 15 11. Therapeutic composition containing a compound of any one of claims 1 to 8 together with pharmaceutically acceptable additives and/or diluents.
12. Use of therapeutic composition according to claim 11 for inhibition of trypsin like serine proteases.
13. Use according to claims 10 and 12 characterised in that trypsin-like serine

proteases are thrombin, factor X_a, kallikrein, plasma, prolyl endopeptidase and Ig AI protease.

14. Therapeutic composition having anti-coagulant or anti-thrombogenic activity containing a compound of any one of claims 1 to 8 together with 5 pharmaceutically acceptable additives and/or diluents.
15. Use of a compound of any one of claims 1 to 8 as an inhibitor of thrombin.
16. Use of a compound of any one of claims 1 to 8 as an inhibitor of vascular remodelling following venous or arterial surgery or other forms of vascular damage.

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/EP 94/00595A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 C07K5/06 C07K5/08 C07K5/10 C07K7/06 A61K37/64

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 5 C07K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 471 651 (SANDOZ LTD.) 19 February 1992 see the whole document ---	1-16
A	EP,A,0 145 441 (E.I. DU PONT DE NEMOURS AND COMPANY) 19 June 1985 see claims; examples ---	1,10-16
A	EP,A,0 293 881 (E.I. DU PONT DE NEMOURS AND COMPANY) 7 December 1988 cited in the application see claims; examples -----	1,10-16

 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

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- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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- *&* document member of the same patent family

2 Date of the actual completion of the international search

20 June 1994

Date of mailing of the international search report

01-07-1994

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Authorized officer

Fuhr, C

INTERNATIONAL SEARCH REPORT

International application No.

PCT/EP 94/00595

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
REMARK : Although claims 10,12,13,15,16 as far as they concern an in vivo treatment, are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound/composition.
2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

The additional search fees were accompanied by the applicant's protest.

No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int'l. Appl. No.

PCT/EP 94/00595

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		CA-A-	2048953	14-02-92
		JP-A-	4330094	18-11-92
		US-A-	5288707	22-02-94
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		DE-A-	3878991	15-04-93
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